

TOXICOLOGICAL PROFILE FOR
RADIUM

Agency for Toxic Substances and Disease Registry
U.S. Public Health Service

In collaboration with:

U.S. Environmental Protection Agency

December 1990

DISCLAIMER

The use of company or product name(s) is for identification only and does not imply endorsement by the Agency for Toxic Substances and Disease Registry.

FOREWORD

The Superfund Amendments and Reauthorization Act (SARA) of 1986 (Public Law 99-499) extended and amended the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA or Superfund). This public law directed the Agency for Toxic Substances and Disease Registry (ATSDR) to prepare toxicological profiles for hazardous substances which are most commonly found at facilities on the CERCLA National Priorities List and which pose the most significant potential threat to human health, as determined by ATSDR and the Environmental Protection Agency (EPA). The lists of the 250 most significant hazardous substances were published in the Federal Register on April 17, 1987, on October 20, 1988, on October 26, 1989, and on October 17, 1990.

Section 104(i)(3) of CERCLA, as amended, directs the Administrator of ATSDR to prepare a toxicological profile for each substance on the list. Each profile must include the following content:

- (A) An examination, summary, and interpretation of available toxicological information and epidemiological evaluations on the hazardous substance in order to ascertain the levels of significant human exposure for the substance and the associated acute, subacute, and chronic health effects,
- (B) A determination of whether adequate information on the health effects of each substance is available or in the process of development to determine levels of exposure which present a significant risk to human health of acute, subacute, and chronic health effects, and
- (C) Where appropriate, an identification of toxicological testing needed to identify the types or levels of exposure that may present significant risk of adverse health effects in humans.

This toxicological profile is prepared in accordance with guidelines developed by ATSDR and EPA. The original guidelines were published in the Federal Register on April 17, 1987. Each profile will be revised and republished as necessary, but no less often than every three years, as required by CERCLA, as amended.

The ATSDR toxicological profile is intended to characterize succinctly the toxicological and adverse health effects information for the hazardous substance being described. Each profile identifies and reviews the key literature (that has been peer-reviewed) that describes a hazardous substance's toxicological properties. Other pertinent literature is also presented but described in less detail than the key studies. The profile is not intended to be an exhaustive document; however, more comprehensive sources of specialty information are referenced.

Foreword

Each toxicological profile begins with a public health statement, which describes in nontechnical language a substance's relevant toxicological properties. Following the public health statement is information concerning significant health effects associated with exposure to the substance. The adequacy of information to determine a substance's health effects is described. Data needs that are of significance to protection of public health will be identified by ATSDR, the National Toxicology Program (NTP) of the Public Health Service, and EPA. The focus of the profiles is on health and toxicological information; therefore, we have included this information in the beginning of the document.

The principal audiences for the toxicological profiles are health professionals at the federal, state, and local levels, interested private sector organizations and groups, and members of the public.

This profile reflects our assessment of all relevant toxicological testing and information that has been peer reviewed. It has been reviewed by scientists from ATSDR, the Centers for Disease Control, the NTP, and other federal agencies. It has also been reviewed by a panel of nongovernment peer reviewers and is being made available for public review. Final responsibility for the contents and views expressed in this toxicological profile resides with ATSDR.



William L. Roper, M.D., M.P.H.
Administrator
Agency for Toxic Substances and
Disease Registry

CONTENTS

FOREWORD	iii
LIST OF FIGURES	ix
LIST OF TABLES	xi
1. PUBLIC HEALTH STATEMENT	1
1.1 WHAT IS RADIUM?	1
1.2 HOW MIGHT I BE EXPOSED TO RADIUM?	2
1.3 HOW CAN RADIUM ENTER AND LEAVE MY BODY?	3
1.4 HOW CAN RADIUM AFFECT MY HEALTH?	3
1.5 WHAT LEVELS OF EXPOSURE HAVE RESULTED IN HARMFUL HEALTH EFFECTS?	3
1.6 IS THERE A MEDICAL TEST TO DETERMINE WHETHER I HAVE BEEN EXPOSED TO RADIUM?	8
1.7 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?	8
1.8 WHERE CAN I GET MORE INFORMATION?	8
2. HEALTH EFFECTS	9
2.1 INTRODUCTION	9
2.2 DISCUSSION OF HEALTH EFFECTS BY ROUTE OF EXPOSURE	9
2.2.1 Inhalation Exposure	9
2.2.1.1 Death	10
2.2.1.2 Systemic Effects	10
2.2.1.3 Immunological Effects	10
2.2.1.4 Neurological Effects	10
2.2.1.5 Developmental Effects	10
2.2.1.6 Reproductive Effects	10
2.2.1.7 Genotoxic Effects	11
2.2.1.8 Cancer	11
2.2.2 Oral Exposure	11
2.2.2.1 Death	11
2.2.2.2 Systemic Effects	12
2.2.2.3 Immunological Effects	12
2.2.2.4 Neurological Effects	12
2.2.2.5 Developmental Effects	12
2.2.2.6 Reproductive Effects	12
2.2.2.7 Genotoxic Effects	12
2.2.2.8 Cancer	12
2.2.3 Dermal Exposure	13
2.2.3.1 Death	13
2.2.3.2 Systemic Effects	14
2.2.3.3 Immunological Effects	14
2.2.3.4 Neurological Effects	14
2.2.3.5 Developmental Effects	14
2.2.3.6 Reproductive Effects	14

2.2.3.7	Genotoxic Effects	14
2.2.3.8	Cancer	14
2.2.4	Other Routes of Exposure	14
2.2.4.1	Death	15
2.2.4.2	Systemic Effects	15
2.2.4.3	Immunological Effects	17
2.2.4.4	Neurological Effects	17
2.2.4.5	Developmental Effects	17
2.2.4.6	Reproductive Effects	17
2.2.4.7	Genotoxic Effects	17
2.2.4.8	Cancer	18
2.3	TOXICOKINETICS	19
2.3.1	Absorption	19
2.3.1.1	Inhalation Exposure	19
2.3.1.2	Oral Exposure	19
2.3.1.3	Dermal Exposure	20
2.3.2	Distribution	20
2.3.2.1	Inhalation Exposure	20
2.3.2.2	Oral Exposure	21
2.3.2.3	Dermal Exposure	21
2.3.2.4	Other Routes of Exposure	21
2.3.3	Metabolism	22
2.3.4	Excretion	22
2.3.4.1	Inhalation Exposure	22
2.3.4.2	Oral Exposure	22
2.3.4.3	Dermal Exposure	22
2.3.4.4	Other Routes of Exposure	22
2.4	RELEVANCE TO PUBLIC HEALTH	23
2.5	BIOMARKERS OF EXPOSURE AND EFFECT	26
2.5.1	Biomarkers Used to Identify or Quantify Exposure to Radium	27
2.5.2	Biomarkers Used to Characterize Effects Caused by Radium	27
2.6	INTERACTIONS WITH OTHER CHEMICALS	28
2.7	POPULATIONS THAT ARE UNUSUALLY SUSCEPTIBLE	28
2.8	ADEQUACY OF THE DATABASE	28
2.8.1	Existing Information on the Health Effects of Radium	29
2.8.2	Identification of Data Needs	29
2.8.3	On-going Studies	34
3.	CHEMICAL AND PHYSICAL INFORMATION	37
3.1	CHEMICAL IDENTITY	37
3.2	PHYSICAL AND CHEMICAL PROPERTIES	37
4.	PRODUCTION, IMPORT, USE, AND DISPOSAL	43
4.1	PRODUCTION	43
4.2	IMPORT	43
4.3	USE	43
4.4	DISPOSAL	43

5.	POTENTIAL FOR HUMAN EXPOSURE	45
5.1	OVERVIEW	45
5.2	RELEASES TO THE ENVIRONMENT	45
5.2.1	Air	45
5.2.2	Water	47
5.2.3	Soils	47
5.3	ENVIRONMENTAL FATE	48
5.3.1	Transport and Partitioning	48
5.3.1.1	Air	48
5.3.1.2	Water	48
5.3.1.3	Aquifers, Sediments, and Soils	49
5.3.1.4	Plants and Animals	50
5.3.2	Transformation and Degradation	50
5.3.2.1	Air	50
5.3.2.2	Water	51
5.3.2.3	Soil	51
5.4	LEVELS MONITORED OR ESTIMATED IN THE ENVIRONMENT	51
5.4.1	Air	51
5.4.2	Water	51
5.4.3	Soil	53
5.4.4	Other Media	54
5.5	GENERAL POPULATION AND OCCUPATIONAL EXPOSURE	54
5.6	POPULATIONS WITH POTENTIALLY HIGH EXPOSURES	55
5.7	ADEQUACY OF THE DATABASE	55
5.7.1	Identification of Data Needs	56
5.7.2	On-going Studies	57
6.	ANALYTICAL METHODS	59
6.1	BIOLOGICAL MATERIALS	59
6.2	ENVIRONMENTAL SAMPLES	60
6.3	ADEQUACY OF THE DATABASE	62
6.3.1	Identification of Data Needs	62
6.3.2	On-going Studies	64
7.	REGULATIONS AND ADVISORIES	65
8.	REFERENCES	69
9.	GLOSSARY	89
	APPENDIX A	109
	APPENDIX B	111

LIST OF FIGURES

2-1	Existing Information on Health Effects of Radium	30
3-1	Uranium and Thorium Isotope Decay Series Showing the Sources and Decay Products of the Four Naturally-Occurring Radium Isotopes . . .	41
5-1	Frequency of Sites with Radium Contamination	46

LIST OF TABLES

1-1	Human Health Effects from Breathing Radium	4
1-2	Animal Health Effects from Breathing Radium	5
1-3	Human Health Effects from Eating or Drinking Radium	6
1-4	Animal Health Effects from Eating or Drinking Radium	7
3-1	Chemical Identity of Radium	38
3-2	Physical and Chemical Properties of Selected Radium Compounds . . .	39
3-3	Selected Radioactive Properties of Naturally Occurring Isotopes of Radium	40
5-1	Estimated Levels of Human Exposure to Radium by Nonoccupational Exposures	52
6-1	Analytical Methods for Determining Radium in Biological Materials	61
6-2	Analytical Methods for Determining Radium in Environmental Samples	63
7-1	Regulations and Guidelines Applicable to Radium	66